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(54) METHODE DE SIMULATION POUR PREDIRE EN FONCTION DU TEMPS UNE COMPOSITION DETAILLEE D'UN FLUIDE PRODUIT PAR UN RESERVOIR

(54) SIMULATION METHOD FOR TIME DEPENDENT FORECAST OF DETAILED COMPOSITION OF A FLUID PRODUCED BY A RESERVOIR

(57)

The invention concerns a simulation method for time dependent forecast of a detailed composition with Q components and/or pseudo-components of a fluid produced by a reservoir, which consists in: representing the reservoir in the form of a grid system (j) whereof each grid constitutes an elementary volume filled with fluid; producing, in a manner known per se, a compositional simulation of the aggregate fluid with N components and pseudo-components (i), N being less than Q. The method is characterised it that it further consists in: e) determining, at each time step (m) and for each grid (j) the liquid and fluid vapour phase composition for detailed modelling with Q components and pseudo-components, on the basis of the vaporised fraction (.theta.jm) and the equilibrium constants (kijm) of the aggregate fluid; f) evaluating for each grid, of time step (m+1), the molar amount of each of the Q components and/or pseudo-components of the itemised fluid on the basis of the values corresponding to time step (m), of the flow rates of the aggregate fluid phases and the liquid and itemised fluid vapour phase compositions determined at step e); and g) evaluating, for each production well, the detailed composition of the fluid produced between times t and t' corresponding to time steps m and m+1, from the aggregate fluid flow rates and the liquid and itemised fluid vapour phase compositions determined at step e).

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(54) **METHODE DE SIMULATION POUR PREDIRE EN FONCTION DU TEMPS UNE COMPOSITION DETAILLEE D'UN FLUIDE PRODUIT PAR UN RESERVOIR**

(54) **SIMULATION METHOD FOR TIME DEPENDENT FORECAST OF DETAILED COMPOSITION OF A FLUID PRODUCED BY A RESERVOIR**

(57) Méthode de simulation pour prédire en fonction du temps une composition détaillée à Q composants et/ou pseudo-composants d'un fluide produit par un réservoir. Elle est du type consistant à: représenter le réservoir sous la forme d'un réseau de mailles (j) dont chacune constitue un volume élémentaire rempli de fluide, réaliser, de façon connue en soi, une simulation compositionnelle du fluide regroupé à N composants et pseudo-composants (i), N étant inférieur à Q, et elle est caractérisée en ce qu'elle consiste en outre à: e) déterminer, à chaque pas le temps (m) et pour chaque maille (j) la composition des phases liquide et vapeur du fluide pour la modélisation détaillée à Q composants et pseudo-composants, à partir des valeurs de la fraction vaporisée (θ_j^m) et des constantes d'équilibre (k_j^m) du fluide regroupé, f) évaluer pour chaque maille, au pas de temps (m+1), la quantité molaire de chacun des Q composants et/ou pseudo-composants du fluide détaillé à partir des valeurs correspondantes au pas de temps (m), des débits des phases du fluide regroupé et des compositions des phases liquide et vapeur du fluide détaillé déterminées à l'étape e), et à g) évaluer, pour chaque puits de production, la composition détaillée du fluide produit entre des instants t et t' correspondant aux pas de temps m et m+1, à partir des débits des phases du fluide regroupé et des compositions des phases liquide et vapeur du fluide détaillé déterminées à l'étape e).

(57) The invention concerns a simulation method for time dependent forecast of a detailed composition with Q components and/or pseudo-components of a fluid produced by a reservoir, which consists in: representing the reservoir in the form of a grid system (j) whereof each grid constitutes an elementary volume filled with fluid; producing, in a manner known per se, a compositional simulation of the aggregate fluid with N components and pseudo-components (i), N being less than Q. The method is characterised it that it further consists in: e) determining, at each time step (m) and for each grid (j) the liquid and fluid vapour phase composition for detailed modelling with Q components and pseudo-components, on the basis of the vaporised fraction (θ_j^m) and the equilibrium constants (k_{ij}^m) of the aggregate fluid; f) evaluating for each grid, of time step (m+1), the molar amount of each of the Q components and/or pseudo-components of the itemised fluid on the basis of the values corresponding to time step (m), of the flow rates of the aggregate fluid phases and the liquid and itemised fluid vapour phase compositions determined at step e); and g) evaluating, for each production well, the detailed composition of the fluid produced between times t and t' corresponding to time steps m and m+1, from the aggregate fluid flow rates and the liquid and itemised fluid vapour phase compositions determined at step e).

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(54) Title: SIMULATION METHOD FOR TIME DEPENDENT FORECAST OF DETAILED COMPOSITION OF A FLUID PRODUCED BY A RESERVOIR

(54) Titre: METHODE DE SIMULATION POUR PREDIRE EN FONCTION DU TEMPS UNE COMPOSITION DETAILLEE D'UN FLUIDE PRODUIT PAR UN RESERVOIR

(57) Abstract

The invention concerns a simulation method for time dependent forecast of a detailed composition with Q components and/or pseudo–components of a fluid produced by a reservoir, which consists in: representing the reservoir in the form of a grid system (j) whereof each grid constitutes an elementary volume filled with fluid; producing, in a manner known per se, a compositional simulation of the aggregate fluid with N components and pseudo–components (i), N being less than Q. The method is characterised it that it further consists in: e) determining, at each time step (m) and for each grid (j) the liquid and fluid vapour phase composition for detailed modelling with Q components and pseudo–components, on the basis of the vaporised fraction (θ_j^m) and the equilibrium constants (k_{ij}^m) of the aggregate fluid; f) evaluating for each grid, of time step (m+1), the molar amount of each of the Q components and/or pseudo–components of the itemised fluid on the basis of the values corresponding to time step (m), of the flow rates of the aggregate fluid phases and the liquid and itemised fluid vapour phase compositions determined at step e); and g) evaluating, for each production well, the detailed composition of the fluid produced between times t and t' corresponding to time steps m and m+1, from the aggregate fluid flow rates and the liquid and itemised fluid vapour phase compositions determined at step e).

(57) Abrégé

Méthode de simulation pour prédire en fonction du temps une composition détaillée à Q composants et/ou pseudo–composants d'un fluide produit par un réservoir. Elle est du type consistant à: représenter le réservoir sous la forme d'un réseau de mailles (j) dont chacune constitue un volume élémentaire rempli de fluide, réaliser, de façon connue en soi, une simulation compositionnelle du fluide regroupé à N composants et pseudo–composants (i), N étant inférieur à Q, et elle est caractérisée en ce qu'elle consiste en outre à: e) déterminer, à chaque pas le temps (m) et pour chaque maille (j) la composition des phases liquide et vapeur du fluide pour la modélisation détaillée à Q composants et pseudo–composants, à partir des valeurs de la fraction vaporisée (θ_j^m) et des constantes d'équilibre (k_j^m) du fluide regroupé, f) évaluer pour chaque maille, au pas de temps (m+1), la quantité molaire de chacun des Q composants et/ou pseudo–composants du fluide détaillé à partir des valeurs correspondantes au pas de temps (m), des débits des phases du fluide regroupé et des compositions des phases liquide et vapeur du fluide détaillé déterminées à l'étape e), et à g) évaluer, pour chaque puits de production, la composition détaillée du fluide produit entre des instants t et t' correspondant aux pas de temps m et m+1, à partir des débits des phases du fluide regroupé et des compositions des phases liquide et vapeur du fluide détaillé déterminées à l'étape e).

Simulation method for time dependent forecast of detailed composition of a fluid produced by a reservoir

The present invention relates to a method of simulation for predicting, as a function of time, a detailed composition of a fluid produced by a reservoir and more particularly a detailed composition of a fluid contained in and produced by an oilfield in which one or more production wells are sunk.

The compositional simulation of an oilfield is commonly used to provide forecast production profiles for the field which make it possible in particular to determine the most suitable production scheme for this field.

The compositional simulation of an oilfield is implemented not by using a real description of the fluid but by using a fluid modelled by a number of components which is smaller than the number of components of the real fluid. Specifically, the number of components of the reservoir fluid being relatively large, a model using all the components would lead to excessive calculation times. This prohibitive calculation time has prompted specialists to group the pure components into pseudo-components, for example a pseudo-component which groups together nitrogen and methane, a pseudo-component which groups together C_3 and C_4 hydrocarbons, etc., and to carry out the simulation of the field on a reduced number N of pure components and of pseudo-components. Such a reduced composition is termed a "grouped composition of the fluid" or "grouped fluid". Generally N represents 5 to 10 components and pseudo-components, this being regarded as sufficient for a proper representation of the behaviour of the reservoir fluid under bottom conditions. The grouped fluid is described by one of the equations of state which are well known to specialists and is adapted to the said grouped fluid.

Before performing the compositional simulation of the field, the reservoir or field is represented in the form of a grid of cells each of which constitutes an elementary volume of the said reservoir. The number of cells may be as many as several thousand and each cell exhibits properties specific to it, such as geometry, porosity, permeability, etc. Moreover, at least one injection well or production well which is sunk into the said reservoir may correspond to certain cells.

Simulation of the field makes it possible to calculate for each cell a number of principal variables of the reservoir fluid, the said variables possibly being the quantity (number of moles) of fluid, the composition or molar fraction of each component and pseudo-component of the grouped fluid and the pressure prevailing in each cell. These variables are known at the instant t=0 (start of the exploiting of the field) and are calculated thereafter by the field simulation at each instant t or timestep m. For each cell, it is possible, on the basis of these principal variables, to calculate any other property of the fluid present in the cell, such as the number of phases, the composition of each phase, etc. For each cell associated with a production well, it is possible, on the basis of these principal variables and of the production constraints imposed, to also calculate the production flow rate and the composition of the fluid produced by the said well.

The thermodynamic properties of the grouped fluid can be calculated using the equation of state associated with it.

Modelling with N components, although it is sufficient to represent the behaviour of the reservoir fluid under bottom conditions, is no longer appropriate for simulating the behaviour of the fluid in plants for its surface exploitation, the latter requiring knowledge of a more detailed composition with Q components and/or

pseudo-components of the fluid produced by the field, Q being greater than N and for example of the order of 16 to 30.

Hitherto, this detailed composition with Q components and/or pseudo-components was obtained on the basis of the grouped composition N by assuming that the composition of the pseudo-components remained constant over time.

Such a procedure gives rise to errors since the composition of the pseudo-components varies over time, especially as a function of the pressure of the field or following the injection of a gas into the field.

Therefore, the detailed composition obtained remains very approximate and does not allow satisfactory prediction of the behaviour of the fluid under the conditions of surface exploitation several years after the start of production.

The purpose of the present invention is to propose a method of simulation predicting a detailed composition of the fluid produced by a reservoir while taking into account the parameters of the reservoir and which is much more accurate, such a prediction being dubbed "delumping" by specialists. "Delumping" consists in predicting what the results of a reservoir simulation would have been if the detailed modelling of the fluid had been used, and to do so on the basis of the results of a simulation carried out by using the grouped modelling of the said fluid.

The subject of the invention is a method of the type consisting in:

a) representing the reservoir in the form of a grid of cells (j) each of which constitutes an elementary fluid-filled volume,

b) defining the fluid by a grouped modelling with N components and pseudo-components (i) and determining an equation of state describing the fluid in this grouped modelling,

c) also defining the fluid by a detailed modelling with Q components and/or pseudo-components, Q being greater than N, and determining another equation of state describing the fluid in this detailed modelling,

d) carrying out, in a manner known per se, a compositional simulation of the grouped fluid with N components and pseudo-components (i), the said compositional simulation making it possible to calculate at least for each cell (j) and at consecutive timesteps (m, m+1, ...) the vaporized fraction (θ_j^m), the liquid/vapour equilibrium constants (k_{ij}^m) for each component (i), the injection or production flow rates (s_{ij}^m) and for each pair of cells (j, h) the flow rates of the liquid phase (u_{ojh}^m) and vapour phase (u_{gjh}^m) of the fluid with N components and pseudo-components, and it is characterized in that it furthermore consists in:

e) determining, at each timestep (m) and for each cell (j) the composition of the liquid and vapour phases of the fluid for the detailed modelling with Q components and/or pseudo-components, on the basis of the values of the vaporized fraction (θ_j^m) and of the equilibrium constants (k_{ij}^m) of the grouped fluid,

f) evaluating for each cell, at timestep (m+1), the molar quantity of each of the Q components and/or pseudo-components of the detailed fluid on the basis of the corresponding values at timestep (m), of the flow rates of the phases of the grouped fluid and of the compositions of the liquid and vapour phases of the

detailed fluid which were determined in stage e), and in

g) evaluating, for each production well, the detailed composition of the fluid produced between instants t and t' corresponding to timesteps m and m+1, on the basis of the flow rates of the phases of the grouped fluid and of the compositions of the liquid and vapour phases of the detailed fluid which were determined in stage e).

According to another characteristic of the present invention, stages e, f and g are implemented at the same time as the carrying out of the compositional simulation of the grouped fluid.

According to another characteristic of the present invention, the results of stage d are stored in memory and then used later for the implementation of stage e, f and g.

The method according to the present invention is implemented in respect of a reservoir consisting, for example, of an oilfield. A field simulation is carried out in a known manner. To this end, the field is represented in the form of a grid of cells, some of the cells or a group of cells being associated with production wells sunk into the oilfield to be exploited.

To reduce the calculation time, the compositional simulation of the field is performed on a limited number N of components and pseudo-components, for example from 5 to 10, defined in the manner indicated earlier, these components and pseudo-components being selected as a function of the nature of the field.
As indicated earlier, the grouped fluid with N components and pseudo-components is described by an equation of state which could for example be the

PENG-ROBINSON equation adapted to the said grouped composition.

The compositional simulation of the field makes it possible to calculate, at each timestep and for each cell, a number of principal variables of the grouped fluid, which variables, in this case, are:

the quantity of fluid: f_j^m

the molar fraction of component i: z_{ij}^m with $1 \leq i \leq N$

the pressure: p_j^m

Through prior measurements, the value of the said principal variables is known at the start of the exploiting of the field, that is to say at the instant t=0 or at timestep m=0.

To go from timestep m to timestep m+1, the compositional simulation comprises several stages which are detailed hereinbelow.

In a first stage and for timestep m, a liquid/vapour equilibrium (flash) calculation is performed on the grouped fluid, for each cell j so as to determine:

the vaporized fraction θ_j^m

the molar fraction of each component i in the liquid phase (x_i^m with i = 1...N) and

the molar fraction of the said component i in the vapour or gas phase (y_i^m with i = 1...N).

These various fractions are determined with the following system of equations:

$$\Phi_i\left(x_{ij}^m,\ldots x_{Nj}^m\right) = \Phi_i\left(y_{ij}^m,\ldots y_{Nj}^m\right) \text{ with } 1 \leq i \leq N$$

$$\left(1-\theta_j^m\right)x_{ij}^m+\theta_j^m y_{ij}^m=z_{ij}^m$$

and

$$\sum_{i=1}^{N}x_{ij}^m=\sum_{i=1}^{N}y_{ij}^m=1$$

in which:

Φ_i is the fugacity of component i.

The vaporized fraction θ_j^m and the equilibrium constants $k_i^m = \frac{y_{ij}^m}{x_{ij}^m}$ with i varying between 1 and N are stored in memory so as to use them in another stage dubbed "delumping" which will be explained later.

In a second stage and for each cell j, certain of the properties of each liquid and gas phase are evaluated, namely the density (ρ_{oj}^m and ρ_{gj}^m), viscosity, saturation and relative permeability.

In a third stage, for each cell j and at timestep m, we calculate the coefficients of the equation for the pressure.

The pressure equations for a cell j at the instant $t + \Delta t$ or at timestep $m + 1$ are:

$$C_{Tj}^m\left(\frac{p_j^{m+1}-p_j^m}{\Delta t}\right)=\sum_{h\in J(j)}T_{jh}^m\left(p_h^{m+1}-p_j^{m+1}\right)+s_j^m$$

To solve these equations, the coefficients to be calculated are:

- the total compressibility C_T^m (fluid + rock),
- the generalized transmissivities

$$T_{jh}^{m} = \sum_{i=1}^{N} \alpha_{ij}^{m} \left(\lambda_o x_i + \lambda_g y_i\right)_l^m . t_{jh}$$

- the source term:

$$s_j^m = \sum_{i=1}^{N} s_{ij}^m$$

In these equations:
h are the cells neighbouring the cell j, $h \in J(j)$, α_{ij}^m is the partial molar volume of component i in cell j at timestep m, λ_{oj}^m and λ_{gj}^m are the mobilities of the liquid (o) and gas (g) phases, t_{jh} is the transmissivity between the centres of cells j and h, l being the upstream cell.

In a fourth stage, the pressure equations are solved for all the cells at the instant $t + \Delta t$, that is to say at timestep $m + 1$.

These equations form a linear system of the type:

$$\underset{\approx}{A} . \underset{\approx}{p} = \underset{\approx}{B}$$

where $\underset{\approx}{p} = \left(p_1^{m+1}, \ldots p_J^{m+1}\right)^T$, J being the number of cells of the grid.

These equations are solved by a standard iterative procedure.

In a fifth stage, the flow rates of the phases between each pair of adjacent cells and for each associated well are calculated at timestep $m + 1$ on the basis of, for example, DARCY's law.

$$u_{ojh}^{m} = -\rho_{oj}^{m}\lambda_{ol}^{m}.t_{jh}\left(p_{h}^{m+1} - p_{j}^{m+1}\right)$$

$$u_{gjh}^{m} = -\rho_{gj}^{m}\lambda_{gl}^{m}.t_{jh}\left(p_{h}^{m+1} - p_{j}^{m+1}\right)$$

ρ being the density and l being the upstream cell with l = j or h.

According to one characteristic of the invention, the flow rates of the phases which will be used in the delumping are stored or kept in memory.

In a sixth stage, the quantity f and the composition z of the grouped fluid are evaluated, in each cell j and at timestep m + 1, on the basis of the values at timestep m, of the flow rates of the phases which were evaluated in the fifth stage and of the compositions of the phases which were calculated in the first stage. To do this, the conservation laws defined by the following equations are applied:

$$f_{j}^{m+1} = f_{j}^{m} - \Delta t\left\{\sum_{h\in J(j)}\left(u_{ojh}^{m} + u_{gjh}^{m}\right) - s_{j}^{m}\right\}$$

$$f_{j}^{m+1}z_{ij}^{m+1} = f_{j}^{m}z_{ij}^{m} - \Delta t\left\{\sum_{h\in J(j)}\left(x_{il}^{m}u_{ojh}^{m} + y_{il}^{m}u_{gjh}^{m}\right) - s_{ij}^{m}\right\}$$

Through an iterative process, the above stages are repeated so as to calculate the principal variables at times $t + \Delta t$, $t + 2\Delta t$, $t + 3\Delta t$, etc. or else at the corresponding timesteps m + 1, m + 2, m + 3 etc., the increment Δt being constant or variable.

Since the flow can occur in any direction between neighbouring cells, all the cells must be processed at each timestep.

According to the present invention, a detailed modelling with Q components and/or pseudo-components is defined together with another equation of state describing the fluid thus modelled.

To do this, the components and/or pseudo-components whose characteristics one wishes to know and which are necessary in order to represent the production fluid under the surface conditions are chosen beforehand. The number Q which is greater than the number N of the grouped composition is generally of the order of 16 to 30. The composition of the detailed fluid with Q components and/or pseudo-components is known at timestep m = 0.

The data stored in the first and fifth stages are used to extend them to the Q components and/or pseudo-components of the detailed composition, in such a way as to perform the "delumping" operation. For the "delumping" operation it is assumed that the reservoir fluid comprises just two non-aqueous phases (liquid and gas) and that the water plays no role in the liquid/gas equilibrium and that none of the other components of the fluid dissolves in the water.

In what follows, upper case letters are used to represent the detailed fluid and lower case letters are used to represent the grouped fluid.

To carry out the "delumping", the further assumption is made that at each timestep m,

- the molar fraction of the vaporized phase in each cell is independent of the number of constituents chosen to model the fluid,

$$\Theta_j^m = \theta_j^m$$

- the number of moles of liquid and of vapour flowing between the cells (U, u) and into or out

of the wells (S, s) is independent of the number of constituents chosen to model the fluid.

$$U_{ojh}^{m} = u_{ojh}^{m} \text{ and } U_{gjh}^{m} = u_{gjh}^{m}$$

$$S_{oj}^{m} = s_{oj}^{m} \text{ and } S_{gj}^{m} = s_{gj}^{m}$$

To perform the "delumping", it is necessary to know the equilibrium constants K for the detailed fluid as well as the molar fraction Θ already determined through the equality $\Theta = \theta$.

The calculation of the equilibrium constants can be performed on the basis of the general equation:

$$Ln[K_I] = \Delta C_0 + \sum^{n} \Delta C_n . \pi_{in} \text{ où } \Delta C_n = C_n^L - C_n^V$$

as indicated by C. LEIBOVICI in his article "A Consistent Procedure for Pseudo-Component Delumping" published in FLUID PHASE EQUILIBRIA, 117 (1996), 225-232.

For a two-parameter equation of state such as the PENG-ROBINSON equation, the generalized LEIBOVICI equation can be written for the detailed fluid in the following manner, so long as there is no binary interaction coefficient:

$$Ln(K_{Ij}^{m}) = \eta_j^m + \beta_j^m \sqrt{a_I} + \gamma_j^m b_I$$

where a_I and b_I are the parameters of the equation of state for the component I and where the parameters η_j^m, β_j^m and γ_j^m are parameters calculated from the equilibrium constants $\left(k_{ij}^{m}\right)$ for the grouped fluid by minimizing the function:

$$f\left(\eta_j^m,\beta_j^m,\gamma_j^m\right)=\sum_{i=1}^{N}\left[\eta_j^m+\beta_j^m\sqrt{a_i}+\gamma_j^m b_i-Ln\left(k_{ij}^m\right)\right]^2$$

The parameters η_j^m, β_j^m and γ_j^m thus obtained will be approximately the same for both modellings, detailed and grouped, of the fluid, the said parameters depending only on the phase parameters, the pressure and the temperature.

In the presence of a binary interaction coefficient, the parameters η, β and γ can be determined by regression.

Therefore, when the detailed composition Z_{Ij}^m is known in cell j at timestep m, the detailed compositions of the liquid and vapour phases can be estimated in the same cell j and for the same timestep m.

$$X_{Ij}^m=\frac{Z_{Ij}^m}{1+\Theta_j^m\left(K_{Ij}^m-1\right)}\qquad Y_{Ij}^m=\frac{K_{Ij}^m Z_{Ij}^m}{1+\Theta_j^m\left(K_{Ij}^m-1\right)}\quad \text{with } 1\le I\le Q$$

I being the component and/or pseudo-component of the detailed composition. These compositions can be normalized so that their sum is equal to 1 if necessary.

When the compositions of the detailed phases are known for all the cells of the grid at timestep m, it is possible to estimate the detailed compositions Z_{Ij}^{m+1} at the next timestep m + 1 from the equations below:

$$Z_{Ij}^{m+1}=\frac{Z_{Ij}^m F_j^m-\Delta t\left(Y_{Ij'}^m S_{oj}^m+X_{Ij'}^m S_{gj}^m\right)-\Delta t\sum_{h\in J(j)}\left(Y_{Ij'}^m U_{gjh}^m+X_{Ij'}^m U_{ojh}^m\right)}{F_j^{m+1}}\quad \text{with } I=1,\ldots,Q$$

where

$$F_j^{m+1}=F_j^m-\Delta t\left(S_{oj}^m+S_{gj}^m\right)-\Delta t\sum_{h\in J(j)}\left(U_{gjh}^m+U_{ojh}^m\right)$$

in which j' = j for a flow rate from cell j to cell h or into the well and j' = h for a flow rate from cell h

to cell j, and j' corresponding to the fluid injected in the case of injection wells, S then being negative, and F is the molar quantity of fluid in each cell with F = f.

The molar flow rate for detailed component I produced by well W at timestep m is given by:

$$S_{WI}^{m} = \sum_{h \in J} X_{Ih}^{m} S_{oh}^{m} + Y_{Ih}^{m} S_{gh}^{m}$$

and the detailed composition of the fluid produced by the well is obtained by normalizing the above flow rates:

$$Z_{WI}^{m} = S_{WI}^{m} / \sum_{I'=1}^{Q} S_{WI'}^{m}.$$

By virtue of the present invention, a detailed composition with Q components and/or pseudo-components is obtained which enables the forecast production profiles to be better defined with enhanced accuracy as compared with the prior methods. This greater accuracy of the forecast production profiles allows a more reliable choice of development scheme (type and size of surface plants, number of wells, etc.), thus resulting in an increase in profitability and a decrease in economic risk.

In the foregoing, certain values obtained in the course of the field simulation are stored or held in memory so as to be used later in the delumping. It goes without saying that these same values could be used directly if it were decided to perform the delumping at the same time as the said field simulation.

Another advantage of the present invention is that the method can be used to calculate the concentration of hydrocarbons present in trace amounts in the fluid produced without having to perform a reservoir

simulation incorporating these hydrocarbons, provided that their equation of state parameters are known.

It should be noted that it is possible to treat the cases where the initial composition of the fluid varies with depth or laterally inside the reservoir, on condition that the initial detailed composition is known at every point of the reservoir.

Two examples are given below to demonstrate the speed and accuracy of the method according to the invention, the tests having been performed on a parallepipedal reservoir model comprising four layers of various permeabilities, with a dip in the x direction.

The predictions were calculated so as to determine the behaviour of the fluid under the surface conditions over a period of 30 years from the start of exploitation, the fluid consisting of a volatile oil.

In the first example, the reservoir includes a water/oil contact, whilst in the second example the reservoir is devoid of water and contains only oil and gas.

In the modelling of the detailed fluid, the fluid is defined by 16 components and/or pseudo-components, as indicated in Table 1, and the binary interaction coefficients are regarded as equal to zero.

In the modelling of the grouped fluid, the fluid is defined by 7 pseudo-components, as indicated in Table 2.

At the temperature of the reservoir, the bubble-point pressure of the volatile oil is 338.5 bar for the detailed fluid and 336.6 bar for the grouped fluid.

Example 1

The initial pressure of the reservoir is 400 bar and the reservoir is depleted through a single well which is drilled near the top of the reservoir. The oil production from the well is 300 m^3 per day and the maximum production of gas is 10^6 m^3 normal per day.

A first compositional simulation of the reservoir was initially performed using the detailed modelling of the fluid with 16 components and/or pseudo-components with the aid of the equations of state adapted to each of the components. At the start, the well produces oil at the abovementioned rate. After around 1250 days, the bubble-point pressure is reached. The flow rate of gas increases continually up to the maximum value of 10^6 N m^3/day which is reached after around 5000 days. The well discharges at this maximum whilst the flow rate of oil decreases until the bottomwell pressure limit is reached at around the 6500^{th} day. After which, the two flow rates, oil and gas, decrease, the simulation terminating at the end of 10950 days (30 years). At this juncture the average pressure of the reservoir is slightly above 50 bar. Water production occurs after 5000 days.

A second compositional simulation of the reservoir is then repeated with the modelling of the grouped fluid with 7 pseudo-components. The production profiles achieved are substantially the same as those of the simulation with the detailed fluid. This suggests that the modelling with 7 pseudo-components is adequate to model the phase behaviour of the fluid under the conditions of the reservoir, at the very least for the purposes of studying the field.

When "delumping" is applied to the results obtained with the second simulation performed on the grouped fluid, it is noted that there is agreement between the results obtained after "delumping" according to the

invention and those obtained with the first simulation which is performed with the aid of the equations of state adapted to each of the 16 components and/or pseudo-components. The difference lies in the fact that the first simulation of the detailed fluid requires a calculation time of 730 seconds whilst the overall calculation time for performing the second simulation (232 s) and the delumping (27 s) is only 259 seconds, that is to say the calculation time is reduced by 65% while still having excellent results.

Example 2

In this example, at the start the reservoir is completely filled with oil. The oil is produced by a well opening into the lower part of the reservoir, with a flow rate of 1000 m^3/day.

Gas is injected through a well, into the upper part of the reservoir, the said injection gas not consisting of a mixture of grouped components, but comprising, by molar percentage, 80% C_1, 15% C_2 and 5% C_3, this composition being used for the simulation with the detailed fluid and also for the "delumping". For the reservoir simulation with the grouped fluid, the composition of the injected gas is represented in molar percentages by 80% N_2 C_1, 15% CO_2 C_2 and 5% C_3C_4; the injection of gas is carried out at a rate of 500 m^3/day for the first 15 years and 900 m^3/day for the next 15 years.

As in Example 1, a first simulation with a detailed fluid model with 16 components is performed. At the start, the flow rate of the injection gas is insufficient to maintain the pressure of the reservoir; therefore, the bubble-point pressure is quickly reached and the gas/oil ratio increases. After 15 years, when the pressure of the reservoir is 120 bar, the flow rate of the injection gas is increased so that after

30 years, at the end of the simulation, the pressure of the reservoir is around 100 bar.

A second simulation with the model of the grouped fluid is performed.

The same effects as in Example 1 are noted, that is to say the model with 7 pseudo-components is still adequate to model the phase behaviour of the fluid under the conditions of the reservoir.

When "delumping" according to the invention is applied to the results of the second simulation, it is noted that, by virtue of the invention, the calculation time for performing the second simulation (173 s) and the "delumping" (18 s) is 191 seconds, this representing around 15% of the calculation time required to perform the first simulation with the model of the detailed fluid, the results being excellent, as in Example 1.

When binary interaction coefficients are introduced, it is noted that the agreement is still satisfactory, even though it is not of the same order as that of Examples 1 and 2. For the heaviest components, the agreement is almost complete. Only the CO_2-C_2 pseudo-components of the grouped fluid gave relatively weak agreement. On the other hand, the gain with regard to the calculation time is still very appreciable since it represents only 35% of the calculation time of the simulation performed on the detailed fluid model with equations of state.

TABLE 1

Component	Initial oil composition (mol. frac.)
N_2	0.00080
CO_2	0.02929
C_1	0.64641
C_2	0.04165
C_3	0.04649
IC_4	0.01569
NC_4	0.02690
IC_5	0.01024
NC_5	0.00948
C_8	0.01915
C_7	0.02003
C_8	0.01925
C_9	0.01391
C_{10}	0.01120
CNG_{1*}	0.06644
CNH_{2*}	0.02309

TABLE 2

Component	Initial oil composition (mol. frac.)
N_2C_1	0.64721
CO_2C_2	0.07094
C_3C_4	0.08908
C_5C_7	0.05890
C_8C_{10}	0.04435
CNG_{1*}	0.06644
CNH_{2*}	0.02309

*CNG_1 and CNH_2 represent the heavy part of the fluid (C_{11}^+), which part is divided into two pseudo-components, one (CNG_1) found principally in the gas and the other (CNH_2) in the oil.

CLAIMS

1. Method of simulation for predicting, as a function of time, a detailed composition of a fluid produced by a reservoir, of the type consisting in:

a) representing the reservoir in the form of a grid of cells (j) each of which constitutes an elementary fluid-filled volume,

b) defining the fluid by a grouped modelling with N components and pseudo-components (i) and determining an equation of state describing the fluid in this grouped modelling,

c) also defining the fluid by a detailed modelling with Q components and/or pseudo-components, Q being greater than N, and determining another equation of state describing the fluid in this detailed modelling,

d) carrying out, in a manner known per se, a compositional simulation of the grouped fluid with N components and pseudo-components (i), the said compositional simulation making it possible to calculate for each cell (j) and at consecutive timesteps (m, m+1, ...) at least the vaporized fraction (θ_j^m), the liquid/vapour equilibrium constants (K_{ij}^m) for each component (i), the injection or production flow rates (s_j^m) and for each pair of cells (j, h) the flow rates of the liquid phase (u_{ojh}^m) and vapour phase (u_{gjh}^m) of the fluid with N components and pseudo-components, and it is characterized in that it furthermore consists in:

e) determining, at each timestep (m) and for each cell (j) the composition of the liquid and vapour phases of the fluid for the detailed modelling with Q components and pseudo-components, on the basis of the values of the vaporized fraction

(θ_j^m) and of the equilibrium constants (k_{ij}^m) of the grouped fluid,

f) evaluating for each cell, at timestep (m+1), the molar quantity of each of the Q components and/or pseudo-components of the detailed fluid on the basis of the corresponding values at timestep (m), of the flow rates of the phases of the grouped fluid and of the compositions of the liquid and vapour phases of the detailed fluid which were determined in stage e), and in

g) evaluating, for each production well, the detailed composition of the fluid produced between instants t and t' corresponding to timesteps m and m+1, on the basis of the flow rates of the phases of the grouped fluid and of the compositions of the liquid and vapour phases of the detailed fluid which were determined in stage e).

2. Method according to Claim 1, characterized in that stages e, f and g are implemented at the same time as the carrying out of the compositional simulation of the grouped fluid.

3. Method according to Claim 1, characterized in that the results of stage d are stored in memory and then used later for the implementation of stage e, f and g.